# PERIPHERAL AND CENTRAL FACTORS IN MEMORY IMAGES OF VISUAL FORM AND COLOR.

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The observations recorded below were made in the Cornell laboratory in 1904-5. The general object of investigation was the appearance, recurrence, and duration, in immediate memory, of visual images of simple figures. The purpose of the study was to ascertain whether figures viewed under uniform conditions of attention differ in reproductivity; and, if so, whether or not these differences can be correlated with certain intrinsic characteristics of the figures, such as size, brightness, color, outline, complexity of contour.[1]

It is a familiar fact in every day experience that, under favorable conditions, memorial images of objects recently experienced tend to recur spontaneously. This fact the experiment sought to turn to account in attacking the problem of the intrinsic liability to recurrence and persistence of images of different figures. The study of the spontaneous recurrence of images was chosen, and voluntary retention expressly forbidden. This procedure, it was believed, promised most toward the elimination of chance reinforcements through associations and purely subjective factors, and was hence more likely to lay bare any relation subsisting between the reproductivity of the figure and size, brightness, etc.

In the first group of observations, the individual durations and the number of appearances of memory images of different figures were recorded. It soon became evident, however, that

[1] This problem, along with the involuntary procedure in the study of images, was suggested by an article by F. Meakin: Mutual Inhibition of Memory Images, *Harvard Psych. Studies*, Vol. I, 1903, 235. In this article, which deals with data relating only to simultaneous observations on a double set of images, the author generalizes with regard to the conditions of reproduction of a *single* image, and concludes that the persistence of an image depends on the activity of its motor accompaniments, and that these motor accompaniments are conditioned by the size, brightness, etc., of the figure. (See I. M. Bentley's critique, *Phil. Rev.*, Vol. XIV, 1905, 253). The method here followed differs from that of Meakin in utilizing one, instead of two figures at a time, thus securing uniform and undivided attention for each; and in recording the duration of each image with greater accuracy.

in the procedure followed the conditions of reproduction were complicated by such factors as affective tone, contrast, familiarity, and associations; and that distinctness and vividness were more constant and more significant factors than mere duration or recurrence. In later groups, accordingly, precautions were taken, especially in the ordering of the series, with a view to further elimination of these disturbances; and a record also of the distinctness and completeness of images was kept.

The second group of experiments was arranged to investigate the relation obtaining between the motor conditions excited by a figure, and the distinctness and duration of the corresponding visual image. The special object here was to verify the conclusions of Meakin[1] and Slaughter[2] as to the dependence of the stability and clearness of the image upon ideated or realized eye-movements. In the third group both voluntary and involuntary recall were studied with a view to discovering whether constant differences in distinctness, completeness and duration hold only for passive attention or run parallel in voluntary and in involuntary recall; and, secondly, whether these differences are correlated with the incentives to sensory attention afforded by the figure.

## Group I. Involuntary Method with Fixation.

### Materials.

Geometric figures cut from colored or neutral-tinted papers were used. These were arranged in five series of four members each, each series being designed to test the dependence of the memory image on a certain factor. The varying factors were outline, complexity of contour, size, color and brightness. The series were made up as as follows:

Ser. I. 1) ellipse, 2) triangle, 3) disc, 4) square—each of medium gray, with a surface of about 12 sq. cm.

Ser. II. A duplication of Ser. I with notched instead of plain line margins.

Ser. III. Discs of the standard gray, of graded sizes, in the ratios 1 : 2 : 4 : 8 and 3-7 cm. in diameter, the next to the smallest identical with the disc of Ser. I.

Ser. IV. Discs of the standard size of Ser. I, of white, light gray, medium gray (the standard gray of Ser. I-III), and black.

Ser. V. Discs of the standard size of Ser. I in saturated red, green, blue, and yellow.

These series were given in the order IV, II, V, I, III. The sequence within the series was haphazard, but constant throughout the whole experiment, being merely reversed every other observation period.

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[1] *Op. cit.*

[2] A Preliminary Study of the Behavior of Mental Images. *Am. J. Psych.*, XIII, 1902, 526.

## METHOD.

The recurrence and duration of the memory images were recorded on a revolving drum by means of a key operated by the observer. The observer sat before a table on which, at a constant distance of 65 cm., stood a large black felt screen. Each figure was exposed in turn at the centre of this screen for 4 sec., during which period the observer steadily fixated a point at the centre of the figure. At the end of the fixation period he received a signal to close his eyes. After a pause of 15 to 20 sec., to permit the fading out of after images, he was given a ready signal, and immediately placed his finger on the key preparatory to recording the course of the memory image. The instructions to the observer were to await as passively as possible the entrance to consciousness of the visual image of the figures, indicating its appearance by a light pressure, its disappearance by release of the key. At the end of the record minute, the observer reported briefly on the completeness and distinctness of the image. On the completion of the series, a general introspective account of the course of the image, associations, direction of the attention, variations in the disposition of the observer, was given. The observations were repeated at intervals of one week, in reverse order. The practice observations are excluded from the averages (Table I), which represent five observations for each figure. A special set was also given in which a full introspective report was taken immediately after each record minute.

The observers [1] represent two rather different types, P. being a good visualizer, while C. was predisposed to motor imagery. At the start, both encountered some difficulty in assuming the semi-passive attitude demanded by the experiment, and in attending simultaneously to the elusive flittings of the memory image and to the manipulation of the key. After a moderate amount of practice, however, the temptation, to voluntary recall or filling out of the image was less insistent and the observer's response to the appearance and disappearance of the image through the pressure and release of the key became fairly automatic. A tendency to the formation of an artificial rhythm was anticipated, but seems to have played a very inconsiderable part.

I. *Introspections.* 1. Manner of appearance of image. As a rule, the memory image appears spontaneously at the beginning of the recording period, or in the preceding after

[1] The writer wishes to acknowledge her indebtedness to the two observers, Miss Peirson and Mr. Coffin; and to Professor I. M. Bentley, under whose direction the investigation was undertaken and completed.

TABLE I.

| | Obs. C. | | | | | | | Obs. P. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) Tot. dur. | (2) Av. dur. | (3) M. V. | (4) Av. No. | (5) M. V. | (6) Tot. dur. for series. | (7) Av. dur. for series. | (1) Tot. dur. | (2) Av. dur. | (3) M. V. | (4) Av. No. | (5) M. V. | (6) Tot. dur. for series. | (7) Av. dur. for series. |
| Ser. I, Disc | 65.7 | 2.2 | .4 | 6 | .8 | 257.5 | 2.2 | 38.6 | 1.1 | .5 | 6.8 | 2.5 | 219.2 | 1.4 |
| Ellipse | 61.5 | 2.2 | .3 | 5.4 | .8 | | | 50.1 | 1.3 | .5 | 7.2 | 3.4 | | |
| Square | 61.4 | 2.2 | .3 | 5.4 | .4 | | | 76.1 | 1.8 | .7 | 8.2 | 1.1 | | |
| Triangle | 68.9 | 2.3 | .4 | 5.8 | .3 | | | 54.4 | 1.4 | .8 | 7.6 | 1.7 | | |
| Ser. II. Disc | 55.7 | 2.1 | .4 | 5.2 | .6 | 265 | 2.3 | 35 | 1.6 | .3 | 4.2 | 3.8 | 236.9 | 1.6 |
| Ellipse | 66.9 | 2.5 | .7 | 5.2 | .9 | | | 75.6 | 1.8 | .8 | 8.2 | 1.9 | | |
| Square | 75.4 | 2.7 | .6 | 5.6 | .9 | | | 74.1 | 1.9 | .9 | 7.6 | 3.6 | | |
| Triangle | 67 | 2.2 | .4 | 6 | .4 | | | 57.2 | 1.3 | .6 | 8.2 | 1.8 | | |
| Ser. III. Size 1 | 56.6 | 2.4 | .5 | 4.6 | .7 | 249 | 2.4 | 62.2 | 1.6 | .8 | 7.6 | 1.6 | 228.7 | 1.8 |
| " 2 | 66 | 2.3 | .5 | 5.6 | 1.2 | | | 37 | 1.1 | .6 | 6.6 | .8 | | |
| " 3 | 56.8 | 2.4 | .6 | 4.6 | 1.1 | | | 37.1 | 1.2 | .7 | 5.8 | 1.8 | | |
| " 4 | 69.6 | 2.4 | .5 | 5.8 | 1 | | | 92.4 | 3.5 | 2.5 | 5.2 | 1 | | |
| Ser. IV. Red | 63.3 | 2.1 | .4 | 5.8 | .9 | 296.7 | 2.3 | 64.1 | 1.7 | .9 | 7.2 | 1.5 | 271.3 | 1.8 |
| Blue | 81.7 | 2.5 | .7 | 6.4 | .8 | | | 58.6 | 1.3 | .5 | 8.4 | 2 | | |
| Green | 90.9 | 2.6 | .5 | 6.8 | .6 | | | 70.3 | 2.1 | 1.3 | 6.6 | 1.5 | | |
| Yellow | 60.8 | 2.1 | .6 | 5.6 | 1.1 | | | 78.3 | 2.2 | 1.1 | 7 | 1.2 | | |
| Ser. V. White | 80 | 2.4 | .5 | 6.6 | 1.4 | 296.7 | 2.3 | 126.4 | 3.5 | 1.9 | 7.2 | 2.6 | 344 | 2.2 |
| Lt. gray | 82 | 2.4 | .5 | 6.8 | 1.3 | | | 67.3 | 1.9 | .9 | 7 | 1.2 | | |
| Med. gray | 68.9 | 2.3 | .5 | 5.8 | 1.2 | | | 47.3 | 1.6 | .5 | 5.8 | 2.9 | | |
| Black | 65.8 | 2.2 | .4 | 5.8 | .7 | | | 103 | 2 | 1.7 | 6.8 | 2.9 | | |
| | | | | | | Gen. av. 2.3 | | | | | | | Gen. av. 1.7 | |

In the above Table, column 1 gives the total duration of memory images in five observations.

2 and 3, the average duration of single image, and mean variation.

4 and 5, average number of images per minute and m. v.

6, total duration of image for series (five observations).

7, average duration of single image for series.

image period. Thereafter it returns at irregular intervals, which usually grow longer toward the end of the minute. On a few occasions, C. reports, the image was apparently evoked by chance twitches of the eyeball or eyelid, by inspiration, or, automatically, by rhythmic pressure of the key. Occasionally, also, the observer reports a faint anxiety at the momentary failure of the image, and a temptation to summon it by movement of the eyes (*O.* C.), by steady fixation, or by recall of detail after detail (*O.* P.).

2. Localization of image. The memory image usually appears in the same direction and at the same distance as did the original. P. distinguishes it from the sensory after image by its position outwards on the screen (the after image appearing

"on the eyelids"), and remarks that "its appearance is often accompanied by the feeling of turning toward it." Occasionally it seems to be situated "in the head," but in this case its distinctness is materially lessened.

That this localization is correlated with the presence of motor elements, actual or ideated, has abundant evidence. Thus C., noting that the memory image usually appears as an object with spatial relations, states that in this case "the feeling of accommodation" is present, with the "tendency to move the eyes and locate the image directly in space." The less real this feeling (of accommodation and convergence?), the less distinct the image. Thus, toward the end of the recording period (C. sometimes reports), the images become less vividly 'visual,' are accompanied by almost no tendency to fixation, and are localized, not in any definite portion of the visual field, but vaguely, 'in the head,'—a type of image described by C. as 'more subjective,' or 'more purely memorial.'[1]

It seems probable that P. also refers to the muscular sensations attending fixation in her less concretely phrased account of the semi-spontaneous recall of images. "I seem to turn my attention toward the place where I expect the image to appear. If I hold my attention on this place, several more images are likely to follow." And again, "my attention vacillates about the place on the board where the image is expected, then settles down, and below unfolds the image, sometimes indistinctly, but as the attention turns more decidedly toward it growing in vividness."

3. Incompleteness of image. Images are rarely complete. The lower right hand portion is most often missing, and the upper left hand portion the most distinct,—a condition possibly correlated with the characteristic grouping of matter on the printed or written page, and the acquired habit of attending primarily to the upper left hand word. In cases where the outline is complete, it is often doubtful whether there are not gaps in the main body of the figure. Whether complete or incomplete in relation to the original, the image is usually reported as flashing in and out as a whole, without growth or alteration.

II. *Duration and Frequency.* 1. General uniformities and variations. Two points are first to be noted, the wide fluctuation in individual values for the same figure, and the smallness of the differences between the averages for different figures. The durations for the figures showing the greatest variation

[1] C.'s feeling of unreality with regard to reproductions of purely retinal elements is interesting in view of his already mentioned 'motor-mindedness.'

swing between the limits 16.8 sec. and 0.4 sec.; and, in a typical case, a mean variation of 0.6 sec. stands with an average of 2.7 sec. (*O.* C.), and a m. v. of 0.9 with an average of 1.9 (see Table I, columns 2 and 3). A glance at the Table will show that, in comparison with these mean variations, the differences between averages for the single figure (column 2), or between averages for the series (column 7), are too slight to be used incautiously as the basis of generalization. It may here be noted that the magnitude of the mean variation is due in part to a progressive shortening of durations which occurred in the course of experimentation, parallel with the decreasing novelty of the stimulus figures; in part to associations, minor distractions, and the like, which often came to light in the introspective notes.

The difference between the records of the two observers is considerable. For P. the images are more frequent and of shorter average duration, the mean variations larger, and the differences both between individual averages and between averages for the series greater. This greater range of variation is possibly correlated with the fact that P.'s general practice in observation was less extended, her attitude toward the experiment less stereotyped and more subject to disturbance than C.'s.

In spite of differences, however, the total durations for the two observers are not widely at variance, and the general rise and fall in values from series to series runs fairly parallel.

2. Duration and outline, complexity, etc. a. Outline. (Ser. I.) For duration of images, angular outlines have a slight advantage over curved (especially for P.). This is no evidence of any intrinsic difference in reproducibility of curves and angles, since both recur unsolicited. It seems rather to be a matter of the absence or presence of a number of definite points to attract and maintain attention during the reproduction period. Apropos of this, the observer remarks that in memory the margin and angles of the square and triangle stand out most distinctly, while in the disc the central portion is equally vivid with the margin. It seems, then, to be a matter of diversity against monotony in maintaining the attention.

b. Complexity. (Ser. II.) The duration averages for notched outlines stand in general above those for plain line contours. This does not, however, indicate any correlation between duration and extent of outline, for the observers report no tendency to follow the outline of the image with the eye. They do report a feeling of effort in the presence of the figures of Ser. II, a difficulty in grasping the whole, which is apparently the correlate of the attraction of the line of regard simultaneously to a large number of similar points, *i. e.*, the notches

on the margin. Hence, as with the angular figures of Ser. I, the factor determining duration would seem to be the incentives to involuntary attention offered by the image during the recording period.

c. Size. (Ser. III.) Increase in size is not paralleled by increase in duration of memory image. The one exception, in the case of size 4 (*O.* P.), is apparently due entirely to reinforcement through verbal associations, 'large' or 'larger,' in some cases, in others to direct comparison through recall of images of smaller size. This complication was apparently accidental, due to a faulty arrangement by which the series emphasized contrasts.

d. Color. (Ser. IV.) For both observers the general average for the color series is higher than that for the plain gray disc —, 2.3 sec. as against 2.2 sec. for C., 1.8 sec. against 1.1 sec. for P. This argues little, however, for the intrinsic reproductivity of color, since the single averages for two of the colors fall below the standard gray disc averages, while the lengthened duration of green is directly traceable to the presence of a persistent association formed during the period of exposure (*O.* C.). For *O.* P. the durations in the color series are subject to great variation, being more at the mercy of chance associations than in the case of the gray series. The ascendancy of yellow must be referred for explanation to the following heading (e), since P. reports that it is recalled as a brightness rather than as a color.— It is to be noted here that the colored discs are less reproducible and recordable as *discs* than are gray ones. They often fail to maintain a definite outline, returning as waves of color rather than as distinct images.

e. Brightness. (Ser. V.) An increase both in average duration and in frequency appears toward the bright end of Ser. V (especially noticeable in the record of *O.* P.) The one irregularity in the series is that of black, which is explained by the fact that with this disc a distinct whitish rim, due to an imperfection in the material, seems to have formed the main feature of the image. In general, however, both observers report that the reproduction of the duller shades of the series was less satisfactory, and, in their estimation, less accurate. This is possibly less a matter of direct correlation between reproductivity and the brightness scale, than of the relation of the different shades to the background in the exposure or reproduction period. The black screen and the darkened field of vision would throw the lighter discs into relief, while the darker discs might be less distinguishable from the background in reproduction. According to the laws of involuntary attention, the contrasting image would, of course, lay the stronger hold on the attention during the reproduction period. On the other

hand, the longer duration of the image for white may be related to the peculiar value of bright light as an incentive to the attention.

A word may here be inserted on the disturbing influence exerted by affective tone, contrast, and the like. Occasionally, the observer reports somewhat ambiguously, of a figure, "more pleasing," or "more interesting, hence easier to recall." As a matter of fact, we find that, both in total number of recurrences and in average duration for single images, C.'s favorite colors, blue and green, hold their own over all other figures except the notched square. This so-called 'pleasantness' is, however, largely reducible to richness of association.

The effect of contrast, novelty, and familiarity on the course of the images is indicated both in the record and in the introspective account of P. As a result, apparently, of repetition, the images of the standard size medium gray disk (which had a place in Ser. I, III, and V) declined in vividness, and toward the end of the investigation altogether failed on three occasions to appear at all. On the other hand, the image of the largest disc (Ser. III), which rarely failed to elicit surprise, and the qualification "large" or "larger," maintained throughout one of the highest duration values.

On the whole, then, so long as duration is made the criterion, the results do not warrant the hypothesis of any direct correlation between reproducibility and size, outline, color, etc., *as such*. It seems probable that these five factors are varyingly effective only in conditioning the attention bestowed on the figure (presumably during the period of reproduction), hence indirectly affecting the duration of the image. On the other hand, distinctness and completeness of image are, as the introspections indicate, less subject to disturbance from outlying factors, hence more purely indicative of the grade of reproducibility in any case.

The problem will, therefore, next be approached from the standpoint of these more significant factors, and their relation to duration examined.

III. *Completeness and Distinctness.* 1. Completeness. All the records show that completeness is not a function of duration. The briefest image may be as complete as that of lengthiest duration. Further, scrappiness of figure would seem to be correlated both with the direction of attention during exposure or reproduction (see I, 3), and with the narrowed range of attention in reproduction. The portions of the visual field lying in indirect vision in the world of perception, or occupying merely the margin of consciousness, seem, in the world of images, to be totally obliterated, or at most present only in the phantom form in which, in popular phrase, the old moon is

said to be present in the new moon's arms. This is illustrated by the report of both observers that when only a crescent out of a whole disc, or the corners of a square, were present in clear consciousness, they could not assert that the remainder of the figure was absent, seeming often to 'feel' rather than to see it.

2. Distinctness. After each record period, a note was made of the relative degree of clearness of the boundaries of the memory image, usually in the terms 'clear' or 'distinct.' Comparison of these observations with the corresponding time records shows that distinctness and duration do not run closely parallel. The individual times in the records reported "unusually distinct" are rarely longer than those for the same figure when reported indistinct. *E. g.*, in a record for the triangle reported "only fairly distinct," the images persist from 2.4 to 4.4 sec., whereas the average duration for that figure is only 1.4 sec. Again, in a record for the square reported as "clear and distinct," the times run from 0.4 sec. to 1.4 sec., while the general average for that figure is 1.8 sec.

At the same time it must be admitted that there is a pretty close relation between the *average* length of duration and the average degree of distinctness for any figure. Thus in P.'s record the figures yielding the longest average duration of image show, with one exception, the largest total of judgments 'distinct.' *E. g.*, the images of the triangle and of the square in Ser. I, the times for which stand at the head of the series, are alone almost invariably reported distinct. In Ser. II, the disc, which has the lowest average duration, has also the majority of judgments 'indistinct.' In Ser. III, size 1 receives the largest number of verdicts 'distinct,' and has also the highest average duration (with the exception of size 4, which is thrown out, on the ground of disturbing associations). In C.'s record this correspondence is less marked, average frequency rather than duration of image varying with distinctness.

It may also be noted in passing that, for distinctness as for duration, angular figures are in the long run more favorable than curved, or, more generally stated, complex are more favorable than simple.

On the whole, then, we may say that, while the distinctness of the individual image is not dependent on its duration, the fact that the image which is typically most distinct tends on the average to maintain itself longest in consciousness suggests two things. Either distinctness is one of the determining factors of duration, or—and this statement seems the more intelligible—both distinctness and duration are dependent on some more fundamental factor. That such a fundamental factor may be found in the capacity of the figure for securing auto-

matic adjustments of the attention during reproduction (or exposure) is suggested by two sets of facts. First, by the correlation existing between distinctness and duration, and complexity; secondly, by the correlation between variations in distinctness and duration for the same figure, and the presence or absence of such incentives to the attention as contrast, novelty, pleasantness, familiarity. When it is recalled that the image during the reproduction period is left entirely to the play of the involuntary attention, it becomes readily conceivable that distinctness is dependent primarily on the presence of one or more features in the figure (*e. g.*, an angle) capable of offering a point of support to the attention, secondarily on reinforcement through some central factor, associative or otherwise; that *duration* of single images is also determined in part by the number of component parts possessed by the figure, and capable of arousing interest in turn; and lastly, that *total duration* or frequency is dependent on distinctness as above determined and is hence a general exponent of the vitality of the image in reproduction. For instance, the square, which presents four definite points or features to the attention in contrast with the monotony of the disc, shows a more persistent tendency to outcrop in consciousness, a greater vitality in maintaining itself, and even when incomplete with reference to the original a greater definiteness of contour than any other member of the series (see Ser. I, *O.* P.).

### Summary for Group I.

The data here collected are negative so far as any immediate correlation between duration or excellence of reproduction and any of the five peripheral factors here considered is concerned. All indications point rather to the significance of central conditions, either in the recording or in the observation period, as the critical factors in determining the character, duration, and frequency of the image. To these central conditions the peripheral factors stand in manifold and varying relations, thus indirectly affecting reproduction.

### Group II. Involuntary Method with Eye-movement.

This variation of the procedure was undertaken in order to ascertain whether the introduction of eye-movements during the period of exposure would materially alter the typical results of Group I. More explicitly, the object was to determine whether a yielding to the natural tendency toward eye-movement during exposure, and the consequent increased tendency toward motor innervations during reproduction, would exert any influence on the distinctness, duration, or completeness of the image; and, if so, whether this influence varies with the

amount of movement. Group I was designed to test the relation of purely sensory factors to reproduction; Group II, that of the other peripheral factor, the motor element.

In this connection, two passages from articles to which reference has already been made may be quoted. Meakin, in more or less explicit support of the Münsterberg theory of the correlation of vividness with the discharge of motor cells, observes that "the mental tracing of a particular boundary seems to condition the sense of the corresponding contents;" and again, "the effect of the activity of the motor elements of the internal impression is to increase distinctness and prolong duration; the sensory processes standing in intimate dependence on the motor." Slaughter's statement, in his study of mental images, is, while somewhat ambiguous, substantially similar. The factors which keep visual images in clear consciousness are, he says, "their own internal organization closely combined with motor elements." Whether these statements are valid or accurate except under peculiar conditions of experimentation is a question on which the following experiment may throw light. It may, however, be suggested in advance that the question whether motor innervations *per se* condition the presence or distinctness of images would seem to be beyond the reach of ordinary introspective methods. For in so far as any correlation between vividness and innervation is open to observation, *i. e.*, when the kinæsthetic elements corresponding to the latter rise above the limen of sensation, it is obviously open to question whether these sensations do not themselves constitute the reinforcing factor.

It may here be noted that the results already obtained show a correlation between vividness and innervation, but only through the medium of the sensations attendant on innervation. These sensations are, moreover, only those accompanying fixation, hence common to all the figures, and apparently varying only in intensity. That is, there is no exact correlation between the character of the innervation and the outline of the figure, such as a theory like that of Meakin's presupposes. It was thought possible, however, that the previous conditions of experimentation, *i. e.*, rigid fixation, might have been unfavorable to the setting up of the necessary associations, and hence to the highest possible grade of distinctness. The procedure with free eye-movement might, on the other hand, be expected to yield a definite correlation between extent or complexity of outline, and duration or distinctness, if such correlation exists.

### *A. With the Figures of Group I.*

#### METHOD.

A set of more or less tentative observations was taken with

each observer, the directions being freely to explore the outline of the figures presented. The figures used and the general order of experimentation were as in Group I. A full introspective account of each minute's record was kept. For purposes of comparison a single set of observations with fixation, with similar pauses for introspection, and at about the same stage of familiarity with the figures, was given.

## RESULTS.

TABLE II.

| | Obs. C. | | | | | | | | Obs. P. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Eye Movement. | | | | Fixation. | | | | Eye Movem't. | | | | Fixation. | | | |
| | (1) Av. dur. | (2) No. | (3) Av. dur. for ser. | (4) Av. dur. for set. | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) |
| I. Disc | 2.7 | 4 | 2.2 | 2.1 | 2.1 | 4 | 2.3 | 2.2 | 1 | 5 | 2.2 | 1.5 | 1 | 6 | 1.3 | 1.7 |
| Ellipse | 1.8 | 5 | | | 2.6 | 3 | | | 2.7 | 5 | | | 1 | 4 | | |
| Square | 2.5 | 4 | | | 2.3 | 5 | | | 1.7 | 8 | | | .7 | 9 | | |
| Triangle | 2.1 | 4 | | | 2.3 | 5 | | | 3.7 | 4 | | | 2.6 | 4 | | |
| II. Disc | 2.1 | 5 | 2 | | 3.3 | 3 | 2.6 | | 1.1 | 8 | 2.5 | | .9 | 7 | 1.2 | |
| Ellipse | 2.1 | 5 | | | 2.6 | 4 | | | 6.9 | 4 | | | 2.3 | 5 | | |
| Square | 2.2 | 5 | | | 2.1 | 4 | | | 1.8 | 9 | | | 1 | 7 | | |
| Triangle | 1.7 | 4 | | | 2.4 | 4 | | | .3 | 4 | | | .8 | 9 | | |
| III. Size 1 | 2 | 5 | 2 | | 2.1 | 5 | 2.1 | | .9 | 9 | 1.1 | | .5 | 10 | 1.2 | |
| 2 | 2.3 | 4 | | | 2.2 | 4 | | | 1.2 | 6 | | | .4 | 3 | | |
| 3 | 2 | 3 | | | 2.1 | 4 | | | 1.1 | 7 | | | .4 | 8 | | |
| 4 | 2 | 2 | | | 2.2 | 3 | | | 1.2 | 8 | | | 3.7 | 6 | | |
| IV. Red | 2.5 | 4 | 2.4 | | 2.5 | 4 | 2.2 | | .9 | 7 | .8 | | 1.3 | 1.2 | 2.9 | |
| Blue | 2.9 | 5 | | | 1.6 | 6 | | | .5 | 5 | | | 2.5 | 6 | | |
| Green | 2.1 | 4 | | | 2.4 | 4 | | | 1.1 | 6 | | | 4.3 | 5 | | |
| Yellow | 2.2 | 4 | | | 1.3 | 5 | | | .6 | 8 | | | 3.7 | 3 | | |
| V. White | 2.5 | 6 | 2.2 | | 1.9 | 5 | 2.1 | | .3 | 6 | 1.2 | | .8 | 8 | 2.2 | |
| Light gray | 2.3 | 5 | | | 2.3 | 5 | | | 3.9 | 4 | | | 3.1 | 5 | | |
| Med. gray | 2 | 5 | | | 2.5 | 4 | | | .2 | 3 | | | 2.6 | 6 | | |
| Black | 2.1 | 5 | | | 1.9 | 4 | | | .6 | 4 | | | 2.4 | 8 | | |

Columns 1, 2, 3, and 4 give the average duration of single memory images, number of images per minute, average duration of image for series, average duration for five series, respectively.

I. The five factors in relation to distinctness and duration. There is even less evidence of any proportionality between duration or distinctness, and size, brightness, amount of outline, etc., than in Group I. None of the five factors seems to have any intrinsic value in reproduction.

II. Movement *versus* fixation, in relation to duration and distinctness.

1. Duration. Comparing the results from the two sets, we find the average duration slightly longer for the procedure with fixation,—1.7 sec. as against 1.5 sec. for P., 2.2 sec. as against 2.1 sec. for C. The average duration for Ser. I and II for P., and for Ser. IV and V for C., is, however, shorter for fixation than for eye-movement, showing no uniformity for the two observers in the alterations effected by eye-movement.

2. Distinctness. The introspective evidence for the two observers is more in accord. First, for distinctness and completeness of image the advantage is with the method of fixation. Secondly, the cases of lengthened duration with eye-movement are correlated, not with greater stability of image, but with the tendency to explore the margin, and with the successive appearance and disappearance of the component parts of the figure. With the new procedure, moreover, the localization of the memory image is less definite, more often to one side of the point of fixation; while the image itself is less stationary, and often seems to float across the field.

These results seemed, on the whole, sufficiently promising to warrant a repetition of the procedure under more favorable conditions; namely, with a set of figures free from the habitual fixation associations of the former method.

### *B. With New Figures.*

#### MATERIALS.

The new series consisted of four figures, of the standard gray tones, of approximately equal surface, and as little suggestive of definite associations as possible. The series was as follows:

1) Pentagon.
2) Octagon.
3) Rectangle.
4) Quadrilateral. (An elongated diamond.)

This series was given twice each observation period, once with fixation and once with freedom of eye-movement during the four seconds' exposure. Steady fixation was facilitated by the use of a head rest. There was also a slight alteration in the manner of exposure, the observer closing his eyes for a second during the removal of the screen, in order to lessen the tendency to eye-movement on exposure. Further, the record of the course of the images was begun five instead of twenty seconds after the exposure of the figure, it being thought desirable to make use of the images which always occurred during this pause, and trial having indicated that the observer could practically abstract from the appearance of the sensory after image. Four repetitions of the whole procedure were given with observer C. only.

## RESULTS.

TABLE III. OBS. C.

| | Eye Movement. | | | | | | Fixation. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) Tot. dur. | (2) Av. dur. | (3) M. V. | (4) Av. No. | (5) Tot. dur. for ser. | (6) Av. dur. for ser. | (1) Tot. dur. | (2) Av. dur. | (3) M. V. | (4) Av. No. | (5) Tot. dur. for ser. | (6) Av. dur. for ser. |
| Rectangle, | 40.7 | 2.2 | .5 | 4.5 | 166.2 | 2.1 | 38 | 2.1 | .4 | 4.5 | 150.1 | 2 |
| Quadrilateral, | 49.4 | 2.1 | .3 | 5.6 | | | 36.8 | 2 | .3 | 4.5 | | |
| Pentagon, | 38.2 | 2.1 | .3 | 4.5 | | | 35.7 | 1.7 | .3 | 5.2 | | |
| Octagon, | 37.9 | 2.1 | .3 | 4.5 | | | 39.6 | 2.3 | .4 | 4.2 | | |

In the above Table columns 1 and 5 give the total duration of image for each figure and for the series as a whole (for four observations); 2, the average duration of image; 3, the mean variation; 4, the average number of images per minute; 6, the average duration for series.

I. *Introspections.* (For eye-movement.) 1. Incentives to reproduction. Occasionally the image seems to be overlooked by some chance eye-movement, as in winking. Moreover, eye-movements, actual or imaged, play a considerable part in the maintenance and completion of the image.

2. Localization. The memory image is more patchy, illusive, and oscillatory, than in the procedure with fixation. The space relations of the image are less definite (as noted in A.), and the image is more often of the 'subjective' type, with the sensations of fixation lacking. The best, most definitely localized images were obtained only when C. had become sufficiently practised with the material to sweep the figure with his eyes, and have left a fraction of the four seconds of exposure for fixation. This device seemed to come to him naturally as a means of escape from the feeling of dissatisfaction attending a mere cursory exploration of the margin.

3. Distinctness and completeness. In general, the images are described as less clear and definite and less complete than in the procedure with fixation, the pentagon and octagon being especially defective. In the most distinct, portions only are clear. Thus the angles only of the rectangle are clearly defined, the intermediate line and surfaces being hazy or absent, while in the quadrilateral the upper acute angle only may be definite.

II. *Duration and Frequency.* 1. Duration of image for

fixation and eye-movement. Comparison of the general averages shows a slight advantage in favor of the procedure with eye-movement, 2.1 sec. as against 2 sec. This (as noted in A) is correlated with the tendency of the image, in the procedure with eye-movement, to rush across the field in indistinct patches, or to build itself up, bit by bit, by real or imaged eye-movement. The averages, also, for individual figures show a longer duration for the eye-movement procedure, except in the case of the octagon. The latter shows a duration of 2.3 sec. for fixation as against 2.1 sec. for eye-movement.

3. Duration in relation to distinctness and completeness. The higher average duration for the procedure with eye-movement is associated with an actual decrease in the distinctness and stability of the image. There is, moreover, no precise correlation between distinctness and completeness, and duration, in the case of any single image. Nevertheless, the rectangle (in the procedure with eye-movement) shows a greater total of judgments 'distinct' and 'complete,' and at the same time a slightly higher *average* duration than any other member of the series. Hence, as in Group I, we may conclude that duration and distinctness, while practically independent of each other, are both furthered, though not absolutely determined, by the same general conditions. The exact nature of these conditions may be brought out more fully in connection with Group III.

## Summary for Group II.

1. The appearance of the image in consciousness is not necessarily dependent on the conscious 'mental tracery' of its boundary. Indeed, under conditions of observation or experimentation which tend to produce such a dependence, the character of the image as a whole is impaired, and the simultaneous appearance of its parts hindered.

2. Fixation during exposure affords the more favorable condition for reproduction,[1] either for the reason that it secures a more impartial distribution of the attention over the figure, hence a clearer impression of the whole, or for the reason that, through the association thus set up between the retinal image and the sensations involved in fixation, these sensations, when repeated or reproduced with the image, constitute a more potent reinforcement of the image than could the fleeting sensations producible by irregular or transitory ocular movements. In short, it is not general ocular movement, as Meakin implies, but certain special motor accompaniments of the state of visual attention, which contribute the effective conditions of visual reproduction.

[1] At least in the case of figures of the size here employed.

## GROUP III. VOLUNTARY AND INVOLUNTARY METHOD WITH FIXATION.

The object of this set of observations was, first, to repeat in more specific fashion the test of the relative effectiveness for reproduction of figures of curved and angular outlines, of relative simplicity or complexity, and of smaller and larger size; secondly, to determine whether the constant differences in duration and distinctness of memory images of different figures are attributable to differences in the incentives offered by the figure to passive attention (during the period of reproduction), or to conditions relatively favorable or unfavorable to reproduction, established during the period of exposure and intrinsic to the image of any particular figure. That is, it was desired to ascertain whether the observed differences between memory images of different figures were intrinsic and necessary, or merely peculiarities resulting from the involuntary procedure thus far adopted in the reproductive period.

### MATERIALS.

Three new series were prepared, each consisting of four similar figures, of the standard gray tone, and of graded sizes, each figure being approximately double the size of that preceding. Series I was made up of discs, Series II of triangles, Series III of discs like those of Series I, in which were inscribed (in Indian ink) triangles similar to those of Series II. It was especially desired to eliminate, so far as possible, any disturbances from familiarity and contrast effects, or from associations. Hence the triangle used was an isosceles with an acute vertex, in place of the equilateral used in Group I; and the figures in each series were given in regular, not haphazard sequence, size 1, 2, 3, 4 in turn, in order to lessen contrast.

### METHOD.

The procedure was in general similar to that in Group II B., except that the procedure for eye-movement was omitted, and voluntary alternated with involuntary recall. Records of voluntary recall of images for one minute were taken for the whole set of figures, alternating with similar records for involuntary reproduction. The whole set of three series was given in a period, twice in all for each procedure, voluntary and involuntary. One observer only, P. of Group I, was employed.

A few supplementary observations were taken with voluntary recall of a single image, after each exposure. Half were given with fixation, half with eye-movement during the four seconds of exposure. In these the results tallied with those obtained by the ordinary method of recording so far as distinctness,

completeness, and ease of recall are concerned. Moreover, differences parallel to those of Group II were observable in the results for fixation and eye-movement.

TABLE IV. OBS. P.

| | | Involuntary. | | | | | | Voluntary. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (1) Tot. dur. | (2) Av. dur. | (3) M. V. | (4) Av. No. | (5) Tot. dur. for ser. | (6) Av. dur. for ser. | (1) Tot. dur. | (2) Av. dur. | (3) M. V. | (4) Av. No. | (5) Tot. dur. for ser. | (6) Av. dur .for ser. |
| I. Circles | 1. | 28 | 1.4 | .5 | 9 | 95.7 | 1.8 | 83.2 | 4.6 | 2.1 | 9 | 203.9 | 2.7 |
| | 2. | 11.8 | 1.1 | .5 | 5 | | | 41.3 | 2.1 | 1.2 | 9.5 | | |
| | 3. | 28.8 | 3.2 | 2.2 | 4.5 | | | 41.5 | 2.4 | 1.6 | 8.5 | | |
| | 4. | 27.1 | 1.7 | .8 | 8 | | | 37.9 | 1.8 | 1 | 10 | | |
| II. Triangles | 1. | 16.8 | 2.1 | 1.9 | 5.2 | 73.1 | 2.3 | 80.4 | 7.3 | 2.4 | 5.2 | 240.5 | 4.1 |
| | 2. | 8.3 | 1.1 | .7 | 7 | | | 65.9 | 4.7 | 1.3 | 7 | | |
| | 3. | 17.8 | 4.9 | 4 | 2 | | | 33.8 | 1.8 | 1 | 9 | | |
| | 4. | 15.8 | 1.2 | .5 | 5.2 | | | 60.4 | 2.7 | 1.4 | 11 | | |
| III. Inscribed triangles | 1. | 32.2 | 2 | 1.2 | 8 | 155.1 | 2.3 | 72.9 | 3.8 | 1.4 | 9 | 240.3 | 3.1 |
| | 2. | 39.6 | 2.6 | 1.4 | 7.5 | | | 56.4 | 2.2 | .7 | 12.5 | | |
| | 3. | 45.6 | 2.6+ | 1.3 | 8.5 | | | 58.9 | 3.2 | 1.2 | 9 | | |
| | 4. | 37.9 | 2.2 | .9 | 8.5 | | | 51.8 | 3.2 | 1.3 | 8 | | |
| | | | | | | Gen. av. 1.1 | | | | | | Gen. av. 3.3 | |

In the above Table columns 1 and 5 give the total durations of image for each figure and series, respectively; 2 and 3, the average duration of image and mean variation; 4, the average number of images; 6, the average duration of image for series.

RESULTS.

I. *Introspections.* 1. The incentives or aids to reproduction employed in voluntary recall are: verbal idea of size; recall of some striking feature (as the angle of the triangle, or the black line in Ser. III), with slow construction of the image about this; movement of the eyes toward the point where the object was seen; and, above all, steady fixation.

2. Discs were more difficult to recall than triangles, or discs with triangles inscribed. In the latter figures, the triangles are more distinct than the surrounding segments.

3. The percentage of judgments "distinct" and "complete" for each series is as follows:

| | Involuntary. | | Voluntary. | |
|---|---|---|---|---|
| | Distinct. | Complete. | Distinct. | Complete. |
| Series I. | 60% | 12% | 75% | 37% |

| | Involuntary. | | Voluntary. | |
|---|---|---|---|---|
| | Distinct. | Complete. | Distinct. | Complete. |
| II. | 75% | 37% | 64% | 60% |
| III. | 37% | 00% | 37% | 12% |

II. *Relative Effectiveness for Reproduction.* The three points to be tested will be examined here, differences in involuntary and voluntary recall being abstracted from.

1. Curves and angles. The triangle has in general the advantage over the disc, in duration, completeness, and distinctness of memory image, as the Table shows. It is, also, as noted above, more readily recalled, and in Ser. III is usually the most positive part of the figure. That this is less a matter of curves and angles in themselves than of complexity as against simplicity, or of varying incentives to fixation, is indicated here as in the previous groups of experiments.

2. Size. The duration, distinctness and completeness of the memory image are not proportionate to the size of the figure reproduced. For involuntary reproduction the next to the largest size invariably overtops the series, both for individual and for total durations. It is noticeable, however, that the corresponding images are reported incomplete, and only moderately distinct. For voluntary recall, the image of the smallest figure maintains itself longest in consciousness. In both procedures (and this seems to be the significant item), the memory image of the smallest figure excels all others both in distinctness and in completeness. Evidently there is, then, an optimal size in visual reproduction, related either to the retinal area of clearest vision, or to the limited field of vision in reproduction.

3. Complexity. The complicated figures of Ser. III have a very slight advantage over the simpler figures (Series I and II) and that mainly in the number of images to the minute. This advantage is partly to be attributed to the fact that in successive images different parts of the figure were accustomed to appear, thus placing the reappearances on a standing different from that of ordinary repetitions. For average duration these figures stand on a level with the triangles in involuntary recall, below them in voluntary. What is more significant, both in distinctness and completeness they rank decidedly below the other figures. But while in this case complexity seems to exercise an unfavorable influence on reproduction, on taking the triangle as an example of relative complexity in comparison with the disc, we find our conclusions reversed. Hence, we conclude that the complexity of the figures of Ser. III exceeds either the limits within which a figure is easily grasped during four seconds' exposure, or the limits of the range of attention for reproduced sensation.

In summary, then, we may say that the figures of small size and of moderate complexity offer the conditions most favorable to reproduction. Whether these conditions are effective during the period of observation or reproduction, or both, must now be considered.

III. *Differences in Reproducibility in Voluntary and Involuntary Reproduction.* With voluntary recall there is a general redistribution of values, with regard to duration, distinctness, and completeness, for the three series. Since, however, this redistribution fails to reduce the memory images of the three types to the same level, and, moreover, reproduces most of the distinctions noted for involuntary recall, the conjecture advanced in Group I, that the superior reproducibility of a figure is due to some intrinsic or accidental qualification for securing a better adjustment of the passive attention during the period of reproduction, seems insufficient to explain the facts. That is, maximal attention during observation is not as uniformly effective for reproduction in the case of figures as in the case of simple sensations, but is complicated by the relation of the figure to certain central conditions. This inequality in the relations of different figures to the central conditions is one that asserts itself under conditions of voluntary as well as involuntary attention, *i. e.*, during either the period of observation or of reproduction. This inequality must now be more closely examined.

It is first to be noted that in Group III, as also in I and II, constant differences in reproducibility are correlated principally with "complexity" of figure. That the image of the more complicated figure should, either in voluntary or in involuntary recall, remain relatively longer in the focus of consciousness than that of the simple figure might be expected if we were to reason by analogy with conditions existing in perception. Gordon [1] has shown that the duration of a single pulse of attention is longer for a complex than for a simple visual object. It is possible that this rule obtains also in the sphere of reproduced sensations, and that the longer durations of Series III (especially in the voluntary procedures where the interruptions in the appearance of the memory image have often the character of fluctuations) are further expressions of this rule. Yet the fact that the most complex figure (that of Ser. III) does not give the longest memory image warns us that this function of complexity is not to be accepted without limitations. The existence of an optimal complexity for reproduction indicates that it is not complexity itself, but the extent to which it

[1] K. Gordon: Meaning in Memory and Attention, *Psych. Rev.*, X, 267.

affords conditions favorable to fixation and attention, which is the determining factor. Moreover, the above quoted facts on the pulse of attention would hardly lead us to anticipate that the image of a complex figure would be not only longer, but also, within certain limits, more complete and distinct than those of other figures. Hence, it seems necessary that the facts be analyzed further in order to arrive at the precise nature of the advantage conferred (in certain cases) by complexity.

Let us look first at the period of exposure for some influence exerted in association with complexity either to enhance the neural excitation underlying reproduction or to furnish associated factors which may serve to reinforce the reproduction. The sensations arising from the innervation of the muscles used to inhibit those eye-movements to which the corners of the figure form incentives seem to offer precisely the factor required. The introspections show a tendency to movement, which is felt and resisted, both in the period of exposure and of reproduction, and which bears a significant relation to the presence and distinctness of the image in the latter period. Since with the simple disc there is apparently no corresponding tendency or resistance, it seems probable that the difference in distinctness and duration of the triangle as compared with the disc is due to the presence in the visual complex of associated fixation sensations of greater intensity, set up again on the appearance of the retinal image in memory, and acting as a reinforcement of this image. In brief, the figure which gives rise to the clearest and strongest fixation sensations has, other things being equal, the best chance in reproduction.[1]

The doubt may of course be raised as to whether these kinæsthetic sensations are actually reinforcing factors, or merely coefficients of the efficiency of attention. The weight of evidence, however, throughout all these groups of experiments, seems to lie on the side of the former hypothesis.

## Summary for Group III.

1. There is an optimal size and complexity for visual reproducibility, dependent on the range of atttention.

2. Conditions obtaining in the period of exposure are critical for reproduction, since certain differences in reproducibility are constant both in voluntary and in involuntary recall.

3. Along with various central factors (familiarity, contrast, association and the like) conditioning the appearance and dis-

[1] *Cf.* Wilhelm Peters: Aufmerksamkeit und Zeitverschiebung in der Auffassung disparater Sinnesreize, *Zeitschr. f. Psych. u. Physiol. der Sinnesorgane*, Bd. XXXIX, 1905, 427, for the value of fixation elements in visual attention.

tinctness of the image, the kinæsthetic elements of fixation play an important rôle.

The results of the investigation may be summed up as follows:

Neither the attributes of the stimulus, qualitative or spatial, nor the general ocular movements to which these attributes may give rise, constitute the important differential factor in visual reproduction. On the contrary, reappearance and persistence, distinctness and general accuracy of reproduction are conditioned primarily upon the relation of the stimulus or image to central conditions, and upon certain special motor phenomena accompanying fixation.